CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-109

January 30, 1981

1. Name of fault.

Pleasanton and related faults (Dublin quadrangle vicinity).

2. Location.

Dublin and Livermore 7.5-minute quadrangles, Alameda and Contra Costa Counties (Figure 1).

3. Reason for evaluation.

New information indicates the need to re-evaluate the Special Studies Zones established in 1974 for the Dublin quadrangle. Also, part of ten-year program (Hart, 1980).

4. References.

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Brown, R.D., Jr., 1970, Faults that are historically active or that show evidence of geologically young surface displacement, San Francisco Bay Region: U.S. Geological Survey Miscellaneous Field Studies Map MF-331.

Burkland and Associates, 1974 and 1975, Preliminary geologic and seismic hazards investigation, Valley Memorial Hospital, Pleasanton, California, May 1974, 30 p. with supplements of September 1974 (18 p.) and January 1975 (108 p.).

California Department of Water Resources, 1964, Alameda Creek watershed above Niles: Chemical quality of surface water, waste discharges, and ground water; 122 p. plus appendices and plates.

Dibblee, T.W., Jr., 1980a, Preliminary geologic map of the Dublin quadrangle, Alameda and Contra Costa Counties, California: U.S. Geological Survey Open-File Report 80-537.

Figure 1 (FER-109). Location of Pleasanton Fault zoned for special studies under the Alquist-Priolo Act (after Hart, 1980) and the study area of FER-109.

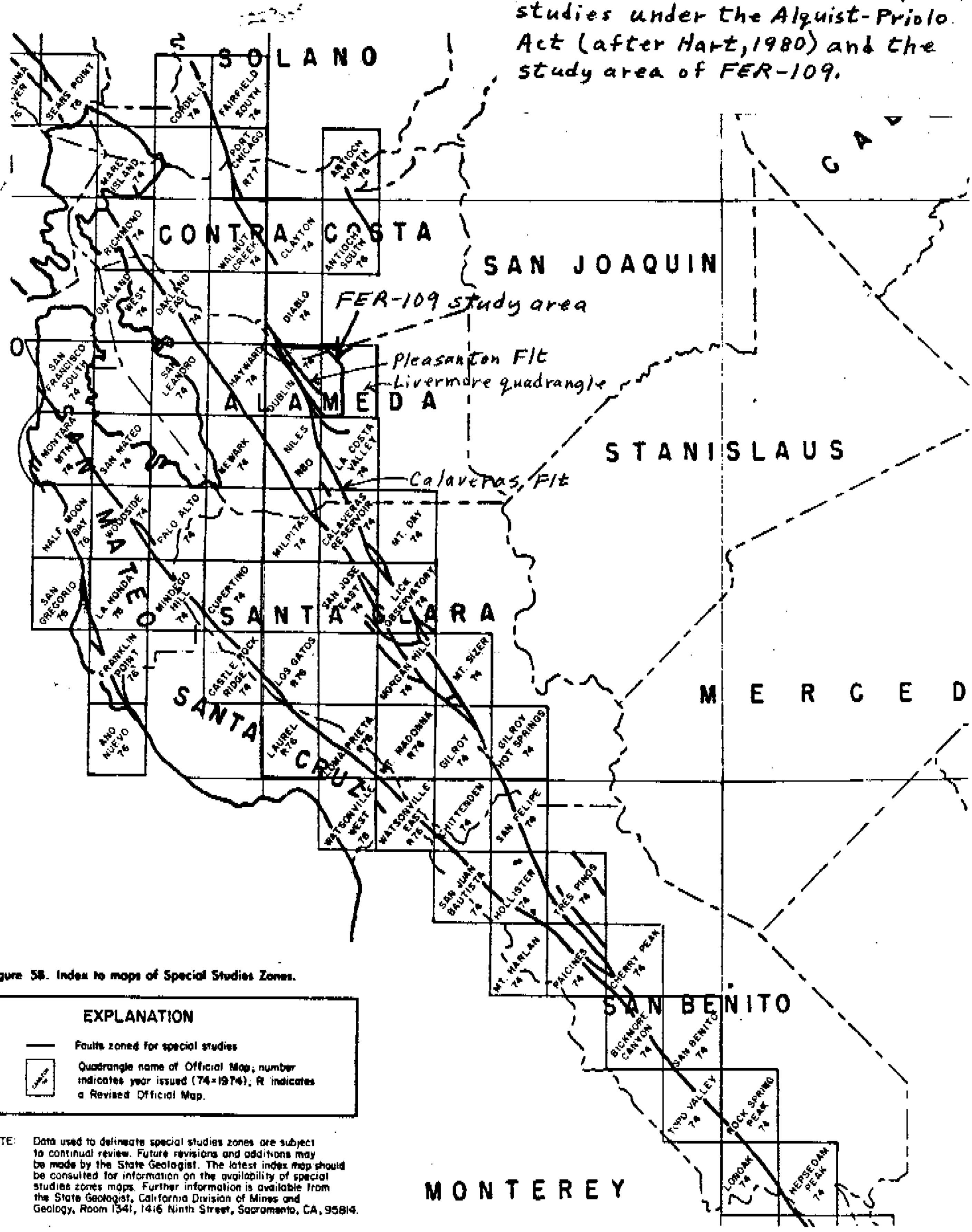

Figure 5B. Index to maps of Special Studies Zones.

EXPLANATION

Faults zoned for special studies

Quadrangle name of Official Map; number indicates year issued (74=1974); R indicates a Revised Official Map.

NOTE: Data used to delineate special studies zones are subject to continual review. Future revisions and additions may be made by the State Geologist. The latest index map should be consulted for information on the availability of special studies zones maps. Further information is available from the State Geologist, California Division of Mines and Geology, Room 1341, 1416 Ninth Street, Sacramento, CA, 95814.

Scale 1:1,000,000
1 inch equals approximately 16 miles

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Gibson, W.M., and Wollenberg, H.A., 1968, Investigation for ground stability in the vicinity of the Calaveras fault, Livermore and Amador Valleys, Alameda County, California: Geological Society of America Bulletin, v. 79, p. 627-638.

Gribaldo, Jones and Associates, 1971a, Report to Gentry Development Company, Dublin, geologic hazard report for subdivision 4087, San Ramon, California.

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Hansen, W.R., 1966, Livermore and Sunol Valleys, evaluation of ground water resources: Geology: California Department of Water Resources, Bulletin No. 118-2, Appendix A (Geology), 79 p., plates.

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Herd, D.G., 1978, Map of Quaternary faulting along the northern Calaveras fault zone, Las Trampas Ridge, Diablo, Dublin, Niles and La Costa 7.5' quadrangles, California: U.S. Geological Survey, Open-File Report 78-307, 5 maps (no text), 1:24,000 scale.

Holden, K.D., 1976, Complete bouguer anomaly map of the Livermore Valley area, California: U.S. Geological Survey Open-File Report 76-761 (map only).

Nason, R.D., 1971, Investigation of fault creep slippage in northern and central California: Unpublished PhD thesis, University of California at San Diego, 231 p.

Radbruch, D.H., 1968, New evidence of historic fault activity in Alameda, Contra Costa, and Santa Clara Counties, California in Proceedings of Conference on Geologic Problems of San Andreas Fault System: Stanford University Publications in Geological Sciences, v. 11, p. 46-54.

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U.S. Coast and Geodetic Survey, 1970, Study of earth movement determined by triangulation, Camp Parks, vicinity of Pleasanton, California: Supplement No. 1, 27 p. (Supplement to August 1965 report of U.S.C.&G.S.).

U.S. Department of Agriculture, 1940, Black and white aerial photographs, vertical, scale 1:20,000 (approximate), BUU-BUT-279-113 to 116, 281-1 to 5, 281-36 to 40, and 341-101 to 108 (available from National Archives, Washington, D.C.).

U.S. Department of Agriculture, 1950, Black and white, vertical aerial photographs, scale 1:20,000 (approximate), BUU and BUT-4G-50 to 59, 4G-92 to 97, and 7G-134 to 137.

U.S. Geological Survey, 1973, Low-sun angle color, vertical photos, scale approx. 1:20,000, 1-50 to 1-57, and 1-91 to 1-93, flown September 21, 1973 (obtained from Rapidcolor, Burbank, CA).

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Yadon, D.M., and Wright, R.H., 1979, Evidence for recent faulting in the Pleasanton area, California in Geological Society of America, Cordilleran Section, April 1979 guidebook, p. 38-44, log a test trench (3 sheets).

5. Review of available data.

Special Studies Zones (SSZ's) were established for the Pleasanton fault and its related branches in 1974, based on the mapping of Ford, et al. (1970), Brown (1970), Radbruch (1968), Smith (1973), and Gribaldo, Jones and Associates (1971a and 1971b). Based on the right-lateral offset of fences reported by Radbruch (1968), the fault was inferred to have historic creep activity. The mapped traces, creep localities, and SSZ boundaries are shown on Figure 2. Other mapped traces also were known (e.g. Thronsen and Hansen, 1963; Hansen, 1966; Ford, 1969), but the zoned fault traces used on the SSZ map were considered to be the most reliable at the time. In addition, geodetic studies of Gibson and Wollenberg (1968) and the U.S. Coast and Geodetic Survey (1970) seemed to verify right-lateral slip along the Pleasanton fault.

Subsequent investigations have since cast considerable doubt on the location, activity, and even the existence of some segments of the Pleasanton fault. The pertinent references are discussed below. The literature also has been reviewed comprehensively by Burkland and Associates (1974-1975) and Wahler and Associates (1980).

Bowen and Crippen (1951, p. 169) appear to be the first to publish a map (small scale) of the Pleasanton fault, although they do not name it or discuss it. They show the fault to extend from Alamo Creek east of the Dougherty Hills southward through east Pleasanton and to connect with what is generally known as the Williams fault.

The Geological Society of Sacramento (1959) first named the fault and show it on a small-scale map as two separate fault traces similar to the 1963, 1964, and 1966 traces of the California Department of Water Resources (CDWR, see below). The Society (p. 4) describes the Pleasanton fault as having expression on 1939 aerial photographs as far south as half a mile south of U.S.

Highway 50 (now I-580). South of there the fault has no surface expression, but its position is marked by a difference in water levels (higher to the east).

The early work of the CDWR on the Livermore Valley water resources resulted in three publications--Thronsen and Hansen (1963), CDWR (1964), and Hansen (1966)--all showing and describing the Pleasanton fault similarly. Hansen (p. 31-32) states that the Pleasanton fault was first located as a "barrier because ground water levels stood as much as 50 feet higher on the east side" just north of Pleasanton. Two faults were interpreted--a main fault and a discontinuous east branch. The northern segment of both faults is visible on 1940 aerial photographs of the U.S.D.A. (especially on BUT-341-105). The fault traces appear as dark tonal lines in the Camp Parks area and as aligned drainages north of there (solid red lines on Figure 2). No surface expression was reported to the south, the existence of the fault being based on differences in water levels. However, the upper aquifer was reported to be continuous across the Pleasanton fault and the fault was not shown as extending to the surface (Hansen, p. 32 and pl. 4). According to CDWR (1964, p. 25-26), and Hansen (p. 19), the upper aquiclude thickens from 25 to 50 feet from west to east across the southern part of the fault, indicating an east-facing scarp. [A west-side up movement is not noted elsewhere along the Pleasanton fault, either in the subsurface or at the surface. Moreover, Ford and Hills (1974, Figure 6) shows no evidence that the "pre-alluvial" (pre-late Quaternary?) surface is offset in any way along the Pleasanton fault.]

Additional studies by CDWR, in cooperation with Alameda County, resulted in three additional reports (Ford, 1969; Ford, et al., 1970; Ford and Hills, 1974) in which the Pleasanton fault traces are relocated and additional traces added. These differences are shown on Figures 2 and 3. The reasons for these differences are not stated, although the later reports cite the same ground water and aerial photo data as the earlier reports. Ford, et al.(1970, p. 130) state that the Pleasanton fault has some effect on the quality of ground water near Pleasanton, but their various maps (Ford, et al., Figure 9, 11, 12, 13) do not clearly support this conclusion. They do refer to two "sag trenches" along one of the traces north of Highway I-580, but do not specifically locate these features (discussed below--under Item 6). A pre-alluvial-surface contour map provides no hint of late Quaternary offset along the Pleasanton fault (Ford, et al., Figure 6). The concealed branch fault west of Dougherty Hills (identified on Figure 2 as "trace A") is attributed by Ford, et al.(1970, p. 134) to a ground water barrier, the water table being about 40 feet lower on the south. However, no evidence of recent offset was noted in several site investigations along this inferred fault (see trench localities AP385, AP387, AP1109, C-463 on Figure 2). The three CDWR reports do not discuss the bases for the other concealed branch faults shown on Figures 2 and 3.

Additional mapping of the Pleasanton fault was done by Brown (1970), based on the interpretation of 1:80,000 scale aerial photos and field checking. He implies that the fault can be traced as a surface feature as far south as Pleasanton, but provides no documentation for this. His traces were plotted on a small-scale map and were used in part to delineate the 1974 SSZ (Figure 2). Radbruch (1968) and Gibson and Wollenberg (1968) also show similar fault traces on small-scale maps, but they credit Thronsen and Hansen (1963) as the source.

Gribaldo, Jones and Associates (1971a and 1971b) were used as sources of data for a short concealed fault inferred to exist at the northern edge of the Dublin SSZ map (Figure 2). This fault was based on shallow anomalies interpreted from seismic refraction and borehole data. However, subsequent trenching (see reports AP24 and AP550, Figure 2, Table 1) indicated the absence of faults in young alluvium.

To the southeast, Smith (1973) interpreted a lineament on small scale aerial photos to be a fault feature as part of his compilation for the 1974 SSZ map. Trenching for a 1971 investigation (see C-388 in Figure 2, Table 1) showed no evidence of recent faulting. This report apparently was not available to Smith. Smith (1973) also mapped an inferred trace of the Pleasanton fault along the western margin of the Dougherty Hills. This fault was based on aerial photo interpretations and was not field checked, other than to determine it was located close to a hump developed in Old Ranch Road. Several trenches across this trace did not reveal the presence of recent faulting, except where Smith's trace crosses the Terrasearch (1979) trace (Figure 2, Table 1) (see below).

Herd (1978) only mapped three short traces for the Pleasanton fault, based on "linear soil patterns" and "subtle scarps" (Figure 2). He did not observe evidence of Quaternary faulting to the north or south of Camp Parks. However, his Verona fault trace (Herd, 1977; 1978), shown on Figures 2 and 3, partly coincides with the Pleasanton fault of Ford, et al. (1970). This segment of the Verona fault was trenched and shown not to be Holocene active (Earth Sciences Associates, 1979; Yadon and Wright, 1979). [The Verona fault of Hall (1958) and Ford, et al. (1970) was discussed in FER-108; the Verona fault of Herd (1977) is evaluated in more detail in FER-104.]

Dibblee (1980a) shows only two short, inferred traces of the Pleasanton fault near Highway I-580 (Figure 2). The traces do not coincide with the work of others. He also shows a concealed, queried fault along the west side of Dougherty Hills. Trenching across that trace revealed no evidence of recent faulting. Dibblee's (1980a, 1980b) Verona fault, similar to Herd's (Figures 2 and 3), is shown to be concealed under recent alluvium and is inferred to cut the Livermore Gravels to the south.

Hall (1958), who mapped the geology of the 15-minute Pleasanton quadrangle which includes the Dublin and Livermore 7.5-minute quadrangles, does not show any faults along the mapped traces of the Pleasanton fault.

Credence for the existence of a Pleasanton fault and for its historic activity has been given by several workers who have observed or inferred historic deformation of the ground surface. Most widely cited is Radbruch (1968), who reported three localities where fences appeared to be offset right-laterally three-to-four inches at Camp Parks (see Figure 2 for localities). She related the offsets to creep on the two branches of the Pleasanton fault mapped by Thronsen and Hansen (1963), stating that the faults were traceable on aerial photos based on "sag ponds and linear depressions." Nason (1971, p. 136-13), however, questioned the creep evidence. In his opinion, the northwest fence that borders Camp Parks is too irregular to verify minor offset. The offset of the south fence at Highway I-580, where it crosses the inferred east trace, was at a property boundary and the fence may have been constructed with an offset. Moreover, he observed no offset in the old highway. He did not observe the south fence where it crosses the main trace. Buildings, fences, roads, and railroad tracks on and near the inferred faults also have been observed at Camp Parks by Burkland and Associates (January 1975 supplement, p. 101-102, Figure 34), Wahler and Associates (1980, p. IV-15 and 16, Figure IV-4), and this writer (see Item 6 below) who were unable to verify creep, although random distortion of fences were noted.

Offset and broken curbs in a residential area near the Walnut School, north Pleasanton, were considered by Wire (1972) to be due to fault creep based on associated geophysical anomalies and the mapping of others (Figure 2). However, observations of Burkland and Associates (1975, p. 50-56) and Wahler and Associates (1980, p. IV-17) failed to verify systematic offset of the curbs, walks and streets. The "creep" features noted are considered to be due to expansive soils and poor constructive practices.

Another locality considered to be possibly related to creep is at Old Ranch Road, 400 feet east of Alcosta Boulevard, in the Dougherty Hills (Figure 2). A linear hump that deformed the road pavement and curbs was considered by Smith (1973) to be possibly related to fault creep. The distressed road was questionably verified in 1974 by a Terrasearch trench investigation (see AP23 on Figure 2 and Table 1), where there was a "sheared zone" in bedrock and a local "deepening of the soil horizon." However, they do not show a fault on their trench log. A later Terrasearch report north of Old Ranch Road, however, did identify a zone of steep easterly-dipping faults in Pliocene Orinda Formation and a groundwater barrier in two trenches (see AP1111, Figure 2 and Table 1). The northerly trench showed a two-foot offset (east side up) of a "soil mixture" along a N5° E-trending easterly-dipping fault. The topsoil unit was not shown to be offset on the trench log, although it was stated to be offset. The southerly trench, only about 50 feet away, did not verify offset of the soil. Other trenches were excavated south of Old Ranch Road by Terrasearch in 1979 (see C-463, Figure 2 and Table 1) and numerous faults were encountered in the Orinda Formation of Pliocene age. Some of these faults were arbitrarily connected (Figure 2) and a building setback zone recommended. Only in Trench 3 (550 feet southeast of the hump, Figure 2) was topsoil reported to be offset. At this locality, the soil is reported to be offset nine inches, with the west side up. The fault could not be traced south of where it is shown on Figure 2. [Although short linear and curvilinear features can be seen on aerial photos, there is no evidence of systematic, recent faulting along the trace mapped by Terratech. Moreover, the distressed road was not observed by this writer to be offset horizontally or vertically. The hump in the road, which reportedly has been repaired several times, most likely is due to extremely expansive soils developed at a groundwater barrier in bedrock.]

A survey network was established in 1964 to detect possible horizontal and vertical movement on the Pleasanton fault (Gibson and Wollenberg, 1968). This network consists of three small quadrilaterals (PFS, PFW and PFE) with bench marks at the corners (see Appendix A). Triangulation surveys in April and May 1964 and June 1965 indicated consistent clockwise rotation (displacements) of bench marks that comprise the quadrilaterals. Gibson and Wollenberg concluded that the displacements supported right-lateral slip across the Pleasanton fault, but that the magnitude of displacement needed to be supported by additional measurements. Levelling surveys of the quadrilaterals and other benchmarks indicated minor subsidence of San Ramon Valley to the west of Camp Parks, much of which was concentrated across the main trace of the Pleasanton fault as mapped by Thronsen and Hansen (1963). Gibson and Wollenberg felt that at least some of the subsidence was related to groundwater withdrawal, but tectonic subsidence was not ruled out.

A resurvey of the quadrilaterals in 1969, indicated about 18 mm of right-lateral movement across the PFS met and 1 cm across the PFW net for the 1964-1969 period (U.S. Coast and Geodetic Survey, 1970). No significant movement was indicated at the PFE quadrilateral.

Subsequent measurements of line lengths at the PFS quadrilateral in 1975 and 1979 by the California Division of Mines and Geology did not indicate significant horizontal movement during the 1969-1979 period (Bennett, 1979). Re-levelling in 1975 indicated some additional subsidence across the PFW quadrilateral and the western part of the PFS quadrilateral, according to Bennett. Bennett's data are summarized in a memorandum of September 6, 1979 and reproduced herein as Appendix A. Table II of Bennett's memorandum recasts the earlier triangulation data into line lengths for each of the earlier surveys at the PFS quadrilateral. These data show that some of the line lengths changes reversed during surveys subsequent to the 1964-1965 period, suggesting that some of the indicated right-lateral displacement may not be due to tectonic slip on the Pleasanton fault. Moreover, the vertical changes measured during the 1965-1975 interval (Table 3 of Appendix A) indicate that differential subsidence across the Pleasanton fault was less than the one year period of 1964-1965. The concentration of horizontal and vertical movements in the 1964-1965 period, and the reversals of movements at certain benchmarks, suggests that the changes recorded at Camp Parks may be largely related to groundwater withdrawal/recharge or expansive soil conditions. Further, U.S. Coast and Geodetic Survey measurements indicate that the Livermore Valley area did not undergo appreciable differential horizontal strain from 1948 to 1964 (Gibson and Wollenberg, 1968). In the absence of regional horizontal strain from 1948 to 1964 and no significant horizontal strain locally at Camp Parks since 1965 (or at least 1969), it seems unlikely that the movements measured in 1964-1965 (1969?) were due to tectonic strain.

Numerous geophysical investigations have been made to locate the Pleasanton fault. Most of these employed detailed seismic refraction and magnetic profiling across development sites. Although many small anomalies are indicated, few of the anomalies identified in reports on file with CDMG could be uniquely related to the Pleasanton fault and none were verified as due to Holocene faulting in the Dublin or Livermore quadrangles. Moreover, the aeromagnetic investigations of Hanna and Brabb (1979) did not reveal anomalies associated with the Pleasanton fault. Deep seismic reflection profiling across the southern segment of the Pleasanton fault (Verona fault of Herd, 1977) south of Pleasanton, also failed to reveal the fault. According to Elgar Stephens (CDMG, 1980 personal communication), this survey was considered somewhat inconclusive because of the lack of deep reflectors.

Two detailed gravity profiles made across Camp Parks and along the Southern Pacific Railroad south of Pleasanton revealed possible minor anomalies (less than 0.5 Mgal), but these were considered inconclusive (Griscom, et al., 1979). An earlier gravity survey of the Livermore Valley failed to identify the Pleasanton fault (Holden, 1976).

The results of exploratory trenching already partly discussed, and of observations of other continuous exposures across the Pleasanton fault is summarized below. The logged exposures are identified on Figures 1 and 2.

1. <u>South of Highway I-580</u>. Trenches excavated to 15 feet deep in alluvium, considered to be late Holocene (5600 ybp, according to Wahler Associates, 1980), cross the entire Special Studies Zones and did not reveal any evidence of near surface faulting. In addition, no faults were identified in the Arroyo Mocho and Arroyo Valle drainage canals, which cross the entire SSZ (Burland and Associates, 1974-1975; and report AP730). Trenches at the proposed County Government Center in Pleasanton failed to find evidence of recent faulting in

the Livermore Gravels (report AP155). South of there, the Pleaanton fault of Ford (1970) and the Verona fault of Herd (1977) and Dibblee (1980b) were not detected as recent features in a carefully logged trench (Earth Sciences Associates, 1979; Yadon and Wright, 1979).

2. Camp Parks. No trenches were excavated here. However, trenches immediately west of Dougherty Road indicate the absence of faulting in terrace and other alluvial deposits of very late Pleistocene and early Holocene (?) ages. Burkland and Associates (1974-1975) did not observe faults in terrace deposits exposed in Alamo Creek.

3. Dougherty Hills. With the exception of the possibly active fault of Terrasearch (1979) discussed above and identified on Figure 2, none of the trenches revealed evidence of active faulting. However, numerous bedrock faults existed in the extensively deformed Orinda Formation. The main trace of Hansen (1966; also Thronsen and Hansen, 1963) is verified as a fault near Old Ranch Road, but not in the linear drainage to the southeast. Although the fault mapped by Terrasearch (1979) is of questionable activity, trenching is inadequate to disprove the existence of active faults in the Dougherty Hills. However, trench data do suggest the absence of any important through-going fault in the Dougherty Hills (as does the aerial photo data discussed under Item 6 below).

4. Branch faults. Trench data indicates the absence of recent faulting for several branch faults shown on Figures 2 and 3.

The Mocho fault of Ford (1969, 1970) and Ford and Hill (1974) is considered to be a major structural feature in the Livermore Valley. The northwestern segments (Figures 2 and 3) are not shown to cut units younger than Pliocene. The existence of the Mocho fault is based on 1) "a line of depressed ridge tops," which Ford and Hill (1974, p. 121-122) speculate as suggesting dip-slip movement (southside up); and 2) an inferred groundwater barrier in Livermore Valley. They show the fault to offset Holocene alluvium (their Sections E-E and F-F), but map the fault as concealed. Gibson and Wollenberg also map a northwestern-most segment of the Mocho fault, which they term the Hill Front fault. The scale of mapping is too small to plot on Figure 2. They (p. 629) state that this fault is marked by a sharp change in relief and a line of springs at the base of the hills. It may coincide with the feature mapped in this study on Figure 4. The fault is not mapped by Dibblee (1980a and 1980b) and Hall (1958) and could not be identified in alluvium in this study (see Item 6 below).

The Parks fault of Hansen (1966), Ford (1969, 1970) and Ford and Hill (1974) is another inferred groundwater barrier that has no obvious surface expression (Figures 2 and 3). According to Ford and Hill (1974, p. 124), it disrupts the sediments below a depth of 100 feet, but the aquifer above that level is unimpeded. Both traces of the inferred fault are crossed by a trench of Burkland and Associates (1974-1975) and no faults were reported in young alluvium.

6. Aerial photograph interpretations; field observations. Aerial photographs of the U.S. Department of Agriculture, Soil Stabilization Service (U.S.D.A. 1940; 1950) and U.S. Geological Survey (1973) were examined stereoscopically for evidence suggestive of recent faulting along the Pleasanton and Mocho faults. The data are plotted on Figure 4. No other evidence for these faults

was observed.

The most notable features, also observed by others (e.g. Thronsen and Hansen, 1963; Ford, et al., 1970; Herd, 1978), are the well-defined dark tonal lineaments observed on U.S.D.A. (1940) photos BUT-341-104 to 106. There is no clear evidence that the features are scarps, although Herd (1978) indicates that all are subtle scarps (two face west and one is uncertain). The features occur in young alluvium and it is evident that they formed within the last few 1000 years. Indeed, the tonal features conceivably may be artificial (e.g., due to farming or drainage lines). In fact, the north end of the eastern trace appears to be the margin of a field (fence line?). The tonal features become abruptly faint or discontinuous to the north and south. Only the middle trace can be traced northward any distance--primarily as a line of drainages (former channel of Alamo Creek?). The closed depressions are both due to drainages being blocked by road construction, although a depressed area apparently is related to oxbow meander at Alamo Creek.

All of the other features to the north and west of Camp Parks are permissive of faulting, but none appear mandatory of recent faulting. The scarps marginal to Dougherty Hills are partly (stream) erosional and partly caused by differential erosion across soft ~~beds~~ or faults in the Orinda Formation. Drainages that cross the scarps and tonal features are not systematically offset, thus precluding significant recent strike-slip or dip-slip faulting. However, minor Holocene faulting could have occurred without detection--particularly if it was somewhat distributive.

Deformation of Old Ranch Road has been considered by other investigators to be suggestive of fault creep. This deformation is a broad hump (perhaps

0.5 to one foot high) in the road pavement and curbs and associated tensional cracks. The hump reportedly has been removed and repaired several times, but each time it reappears. This feature was examined in 1979 and 1980, and neither time could any evidence of horizontal or vertical offset be observed in the road. Trenching to the north and south (see Section 5 above) revealed a zone of steeply east-dipping faults and a groundwater barrier in Orinda Formation aligned with the hump. This coincides with part of the dark tonal line observed on the U.S.G.S. (1973) aerial photos. There was no evidence of systematic soil offset in the trench exposures, although minor soil steps were reported in at least two trenches (Terrasearch, 1979). In the absence of measurable creep, the lack of systematic recent faulting, the presence of extremely expansive soil, and the existence of a groundwater barrier, it seems probable that the road distress is the result of differentially expansive soils along a fault zone. The reported soil offset cannot be explained by any single theory, although faulting cannot be entirely ruled out as a contributing factor.

Observations were made along paved roads, railroad tracks, and fence lines at Camp Parks, Dougherty Road, and Old Ranch Road in 1979, and no evidence of fault distress or systematic offset was noted. Similar observations are reported by Nason (1971), Burkland and Associates (1975) and Wahler Associates (1980). If the north and south fences at Camp Parks had been offset three-to-four inches, as suggested by Radbruch (1968), surely this would have systematically distressed or offset the linear structures within Camp Parks.

Several trenches of Terrasearch, Inc. (1979), observed south of Old Ranch Road, verified the existence of numerous faults in the Orinda Formation (Pliocene), but only one trench revealed evidence of recent soil offset. That was in Trench 4, where the base of the top soil reportedly was offset nine inches (east side down) along a fault dipping 52°E (Terrasearch, 1979). Where observed by me, the surface of the ground showed no fault-related features and no striations were observed or reported on the fault plane. The soil was not offset in a trench 50 feet to the south. It is believed that this apparent offset was due either to differential soil development over contrasting rock units or slight downhill movements along old faults in bedrock. The sense of offset was opposite to that reported north of Old Ranch Road by Terrasearch in 1979 (see AP1111 in Table 1 and Figure 2). Figure 4 identifies the presence or absence of faults where exploratory trenches cross the mapped features.

Other than the features identified on Figure 4, no other evidence was noted for the existence of recent traces of the Pleasanton fault. This specifically includes Trace A and other inferred branches of the Pleasanton fault, shown on Figure 2. Also, no evidence of the Parks fault was noted on the aerial photos. The inferred Mocho fault of Ford et al. (1970) could not be identified for the most part, although the line of springs and associated tonals north of Camp Parks (Figure 4) probably are fault-related. This feature occurs at a break in slope and is a groundwater barrier in bedrock that may be an impervious bed or a bedding plane fault. The Mocho fault of Ford was based on aligned drainages and troughs that are developed by differential erosion on steeply dipping beds that strike west to northwest.

7. Seismicity. The locations of well-located (A quality) earthquakes and principal faults in the Livermore Valley is shown on Figure 5. As can be seen, a number of epicenters lie close to the Pleasanton fault north of Camp Parks, but none exist to the south in the Pleasanton area. A few epicenters

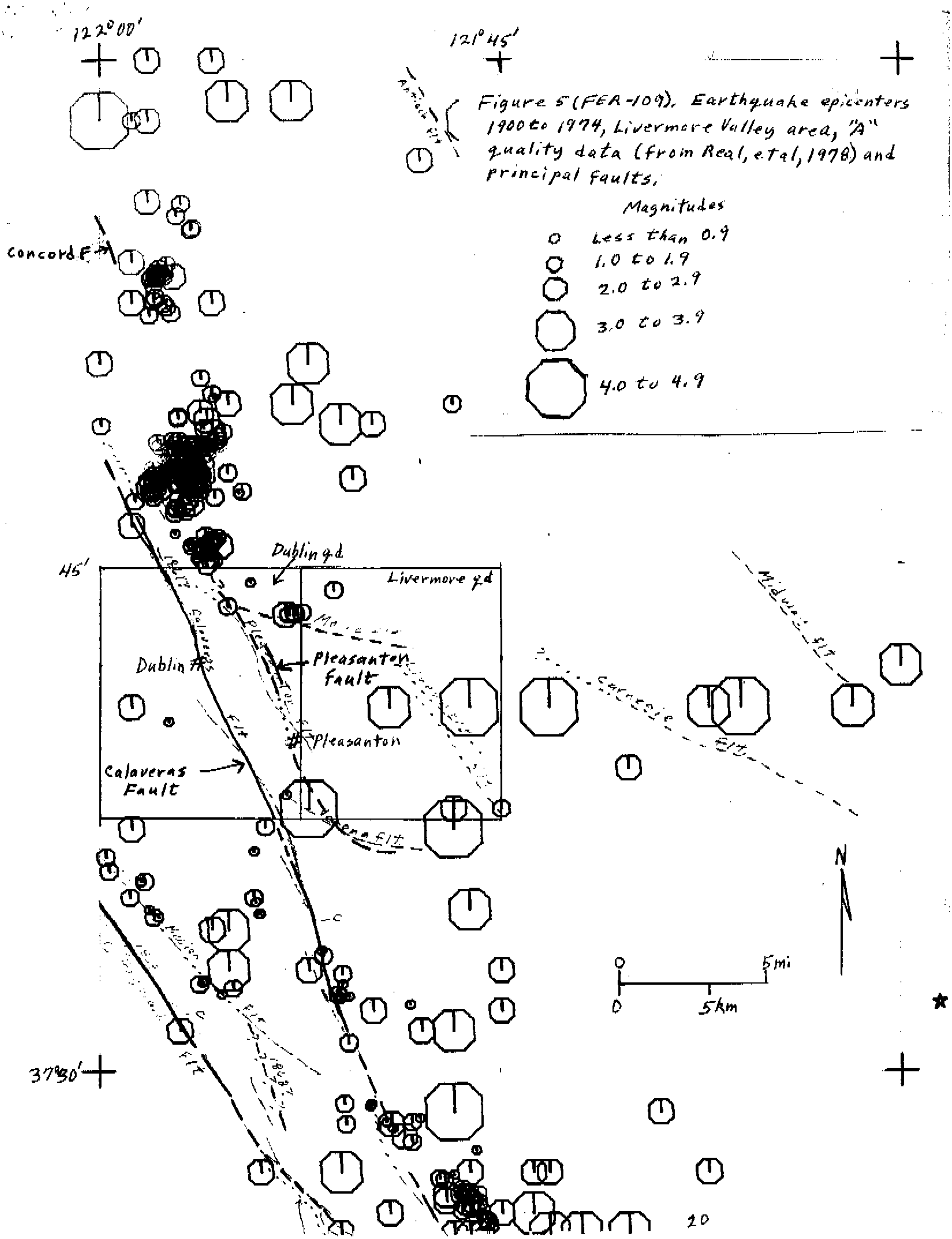


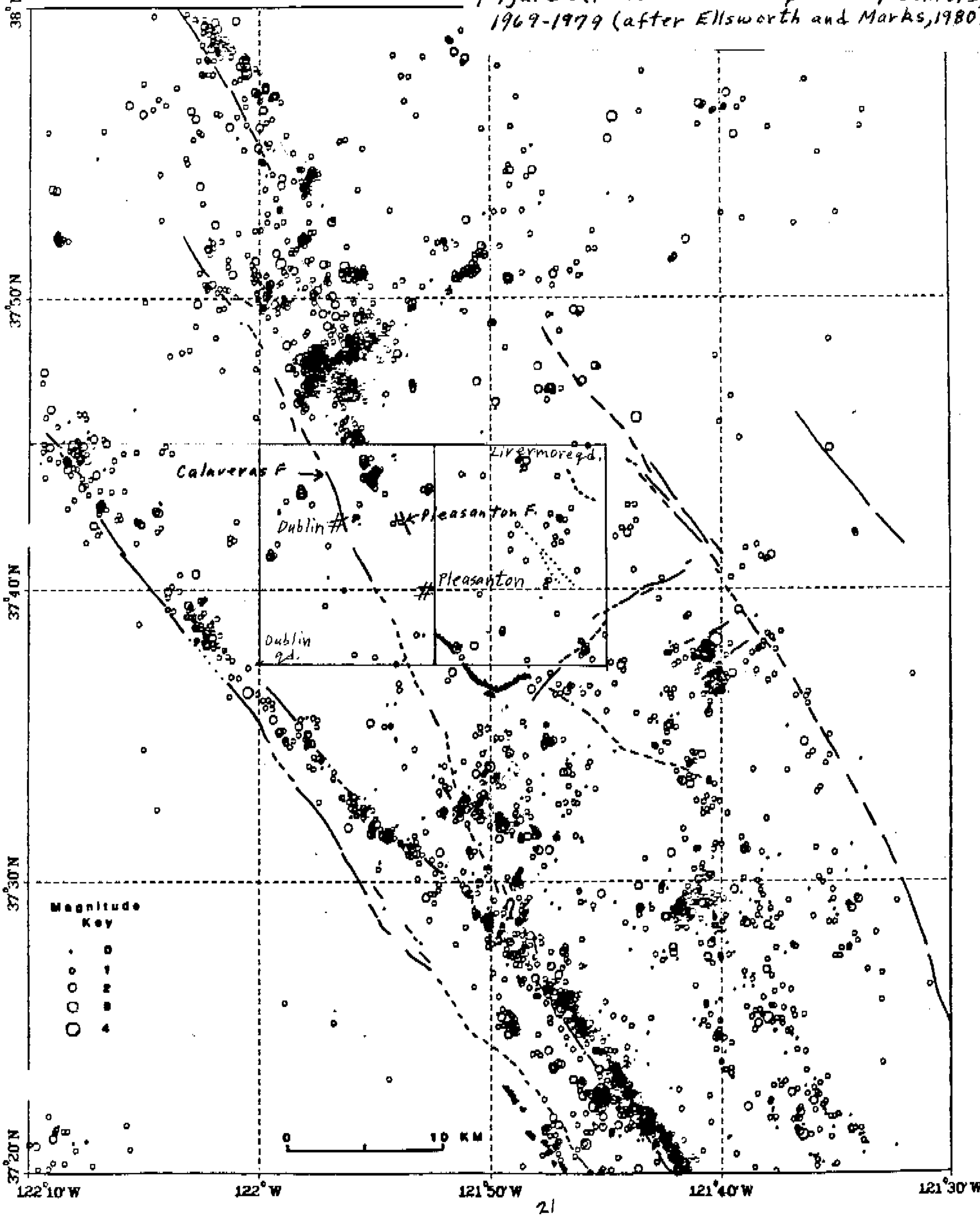
Figure 5 (FEA-109). Earthquake epicenters 1900 to 1974, Livermore Valley area, "A" quality data (from Real, et al, 1978) and principal faults.

LIVERMORE REGION STUDY AREA

1969 - 1979

Figure 3

Figure 6 (FER-109). Earthquake epicenters, 1969-1979 (after Ellsworth and Marks, 1980).



are located near the Mocho fault.

According to Ellsworth and Marks (1980, p. 18), recent seismological evidence indicates that the Pleasanton fault is probably active (see Figure 6). They state that few earthquake epicenters actually are located near the fault (presumably in the Camp Parks area) and "their association with the fault cannot be unambiguously demonstrated. The distribution of earthquake hypocenters and orientation of their focal mechanisms to the north" of Camp Parks strongly suggest that the Pleasanton fault continues to the north along the east side of San Ramon Valley. No evidence of seismicity is associated with the fault south of Camp Parks.

8. Conclusions.

The Pleasanton fault is an inferred fault based on the linear features observed at Camp Parks and the association of assumed groundwater barriers (Thronsen and Hansen, 1963; Hansen, 1966; Ford, 1970; Brown, 1973; Smith, 1973; Gribaldo, Jones and Associates, 1971). Reported offset fences (Radbruch, 1968) and crustal deformation (Gibson and Wollenberg, 1968) at Camp Parks and distress of Old Ranch Road suggested that the fault was historically active and Special Studies Zones consequently were established in 1974.

Subsequent work has raised questions as to the location and recency of faulting for the various strands and branches of the Pleasanton fault and the validity of historic slip attributed to the fault. The following conclusions were drawn regarding certain segments of the fault:

1. Camp Parks area. Three well-defined tonal lineaments are revealed by 1940 aerial photos of the U.S.D.A. (Figure 4). Although the features may be artificially created, they occur in Holocene alluvium and may be caused by faulting. However, the reported creep of

Radbruch (1968) could not be verified. Evidence for horizontal crustal strain is small (maximum 1.8 cm right-lateral slip), confined to a short period of time (1964-1969). Such movement may be related to survey errors and/or subsidence related to ground water changes and expansive soils. The well-defined features cannot be traced more than 2000 feet south of Highway I-580. Only the middle trace can be inferred to extend northward through Camp Parks along a linear drainage (former channel of Alamo Creek) that may or may not be fault-controlled. That trace was not identified in terrace deposits of Alamo Creek, either on aerial photos, in the creek bank, or in exploratory trenches. The inferred fault traces mapped in this study largely coincide with the traces of Hansen (1966).

2. Dougherty Hills segment. There is no evidence of a well-defined, through-going fault observable in this area. The most likely location for a recently active fault is along the aligned drainages where a trace was mapped by Hansen (1966) and this investigator (Figures 2 and 4). However, several exploratory trenches failed to reveal any fault in recent alluvium along this trace. The other mapped faults also were shown by trenching to be inactive or non-existent in several places, with the exception of the Terrasearch (1979) fault. The northern third of this fault reportedly offsets topsoil in some of the trenches and aligns with a ground water barrier and a distressed segment of Old Ranch Road. However, the implied relationship between these observed features and active faulting is to some degree questionable. The southern part of the Terrasearch fault is some-

what inferential in that it is not a mappable surface feature, being projected southward by correlating trench exposures 400 to 800 feet apart. The southern segment of the Terrasearch fault also is of questionable Holocene activity, because, 1) the soil is not offset in any of the trenches, and 2) other bedrock faults are indicated in the trenches. The other features shown on Figure 4 are partly related to bedrock faults, and partly due to differential erosion of contrasting bedrock units. The features do not suggest significant or systematic recent faulting. The seismicity coincidental with Dougherty Hills has been interpreted as caused by right-lateral strike-slip faulting at depth (see below). Although this may relate to some of the surface faults observed, a direct relationship has not been established and no horizontal offset or striations have been observed along any particular fault mapped or inferred.

3. Trace A and nearby traces. There is no evidence that these traces represent surface faults, either on aerial photos or in trenches excavated across them. If a groundwater barrier exists along Trace A, it does not extend to the near surface.

4. Highway I-580 to Pleasanton. Except for the vague tonal lineament extending 2000 feet south from Camp Parks, there is no evidence of faulting in the late Holocene deposits. The groundwater barrier inferred to exist at depth cannot be seen on aerial photos and no faults were reported in deep trenches or in the exposures of Arroyo Mocho and Arroyo Valle.

5. South of Pleasanton. The Pleasanton fault of Ford (1970) and Verona fault of Herd (1977; 1978) and Dibblee (1980 a and b) were trenched and no evidence of Holocene faulting was reported. In fact, no im-

portant faults were exposed in these trenches. There is no evidence of a recent, through-going fault observable on aerial photos.

In summary, it is concluded that, with the possible exceptions at Camp Parks and at Old Ranch Road, the Pleasanton fault is not a well-defined, active fault. There is no surface evidence for this fault south of the Camp Parks area and it is not well-defined and may not be Holocene active in the Dougherty Hills to the north. The well-defined tonal features at Camp Parks may be due to faulting, although that has not been clearly demonstrated. If they are fault-related, then faulting has occurred during Holocene time.

The Parks fault is an inferred groundwater barrier whose location is open to interpretation (Figures 2 and 3). There is no evidence that this is a surface feature.

The Mocho fault is inferred by Ford (1970) to exist based on generalized geomorphic features and an assumed groundwater barrier. No evidence for recent faulting could be seen in the hills, although older bedding-plane faults may exist in the steeply dipping beds. The groundwater barrier north of Camp Parks (Figure 4) may be a fault, but it does not appear in the alluvium, nor does it offset the drainages that cross it. No evidence for faulting could be detected in the alluvium of Livermore Valley.

9. Recommendations.

It is recommended that the Special Studies Zones established for the Pleasanton fault be revised as follows:

1. Camp Parks area. Re-zone based on the three traces shown on Figure 4. These well-defined features are of Holocene age and may be fault-related.

2. Dougherty Hills segment. Revise SSZ to include only the fault trace of Terrasearch (1979)(shown on Figure 2). Although the southern part of this fault is questionable, the northern end is locatable and reportedly Holocene active. The other inferred faults (Figures 2 and 4) do not meet the zoning criteria.

3. Trace A and nearby traces. Delete the trace and the SSZ. There is no evidence of interconnecting surface faults between the Pleasanton and Calaveras faults.

4. Highway I-580 to Pleasanton. Delete all traces, except the easterly trace (shown on Figure 4) that extends 2000 feet south of the highway. There is no evidence of surface faulting associated with the other inferred groundwater barriers.

5. South of Pleasanton. Do not zone. There is no evidence for the existence of well-defined, Holocene faults in that area.

It is also recommended that the Parks and Mocho faults not be zoned. These faults are largely inferential and there is no surface evidence of Holocene faulting.

10. Report prepared by Earl W. Hart, January 31, 1981

Earl W. Hart

EARL W. HART
Senior Geologist
CEG 935

EWH/clz

TABLE 1 (FER-109). Unpublished Fault-investigation Reports, providing observational data on the Pleasanton fault, Dublin and Livermore quadrangles. Trench locations referred to are plotted on Figures 2 and 3. File numbers refer to reports filed under the Alquist-Priolo Act (AP-), or consulting reports filed informally (C-) at CDMG, Ferry Building, San Francisco, CA.

CDMG File #	Investigation Firm (or geologist)	Site Description and locality	Date of report(s)	Comments
AP-23	Terrasearch, Inc.	Subdivision 4650, San Ramon	July 1974	160' long trench exposed shears in bedrock and a locally thickened soil which were interpreted as a NW-trending fault; fault considered to be potentially active; inconclusive, as soil not offset, no distinct fault found, and no ground-water barrier (see AP-1111).
AP-24	Terrasearch, Inc.	Subdivisions 3843, 3844, 3845, 4171, 4517, 4656, San Ramon	July 1974 Nov. 1974 May 1977	Three trenches--70', 160', and 500' long--in young alluvium; no faults reported.
AP-155	D.L. Carpenter	East County Government Center, Pleasanton	Oct. 1975	Extensive trenching of hill site in Livermore Gravels. No active faults reported.
AP-312	Soil Foundation Systems	Tract 4831, San Ramon	Feb. 1976 July 1976	Two short trenches and long sewer trench logged; no faults reported in young alluvium. Trenches 5' to 8' deep.
AP-385	United Soil Engineering and Engeo, Inc.	Tract 4968, San Ramon	Dec. 1976 June 1979	Sewer trenches in young alluvium; no faults reported.
AP-387	Terrasearch, Inc. and United Soils Engineering	Tracts 4441, 4440, 4196 and 4481, Rancho San Ramon	Nov. 1974 Nov. 1976 Aug. 1980	Minor fault reported in alluvium in two adjacent trenches at Pine Valley Road west of Alcosta Blvd. Retrenching in 1980 failed to verify fault.

TABLE 1 (cont.)

CDMG File #	Investigation Firm (or Geologist)	Site Description and locality	Date of report(s)	Comments
AP-550	JCP Geologists	St. Denis Drive, San Ramon	Sept. 1977 Oct. 1977	Two short trenches across geophysical anomaly; no fault reported in young alluvium.
AP-730	Applied Soil Mechanics	Tract 3359, Pleasanton	Aug. 1977	Banks of Arroyo Valle exposed and logged [based on Burkland and Assoc. (1975)]. No faults reported in young alluvium dated at 5100 ybp. Eastern 300' of logged section poorly exposed. Beds dip gently to east.
AP-731	Judd Hull & Assoc.	West Angela St., Pleasanton	May 1977	Shallow trench in young alluvium; no fault found.
AP-790	Terrasearch, Inc.	Alcosta Blvd. and Montevideo Dr., San Ramon	May 1976	80' trench in Pliocene rocks; possible fault, but no evidence of recency. Other trenches to N encountered possibly active faults in Diablo quadrangle.
AP-1109	Engeo, Inc.	Alcosta Blvd., San Ramon Village	June 1979 Oct. 1979	10' deep, 267' long trench in young alluvium; no fault found.
AP-1111	Terrasearch, Inc.	Tract 4450, Alcosta Blvd.	May 1979 Aug. 1979	Four trenches, 8' deep in Orinda Formation (Pliocene) and alluvium. N-trending fault in one trench offsets bedrock and older soil; creates groundwater barrier. Offset soil not found in adjacent trench. Faults shown on SSZ map not verified in trenches. Bump in Old Ranch Road considered to be fault-related.
AP-1128	Engeo, Inc.	Komandorski Village	May 1979	Five short trenches in alluvial terrace deposits; no faults found and alluvial strata correlate between trenches.
AP-1219	United Soil Engineering	Black Ave. (residential), Pleasanton	July 1979	Two short 12' deep trenches in young alluvium; no faults reported.

FER 109

TABLE 1 (cont.)

CDMG File #	Investigation Firm (or Geologist)	Site Description and Locality	Date of Report(s)	Comments
AP-1248	Terrasearch, Inc.	Linvale Project, north Pleasanton	Oct. 1980	330' long, 8' deep trench in young alluvium; no fault reported.
AP-1297	Wahler & Assoc.	Pleasanton Business Park near Hwy I-580	Feb. 1980	2200' of trenching to 16' deep in young alluvial deposits 0-5600 years old; no faults found. In-depth summary of literature.
C-8	Gribaldo, Jones & Assoc.	Subdivision 4170, San Ramon	Sept. 1971	Anomalous zone inferred from seismic refraction and borehole correlations indicate possible groundwater table offset. Fault inferred and shown on 1974 SSZ map.
C-9	Gribaldo, Jones & Assoc.	Subdivision 4087, San Ramon	May 1971	Same comments as C-8.
C-45	Burkland & Assoc.	Tract 3364, Pleasanton	Jan. 1973 Mar. 1973	1400' of trenching in young alluvium; no faults reported.
C-313	Burkland & Assoc.	234 Main St., Pleasanton	Sept. 1975	Two trenches, one 65' long; no faults reported.
C-333	Harding, Miller, Lawson & Assoc.	Hopyard Road site near Pleasanton	Feb. 1972	1700' of trenching in western half of SSZ; trenches 8-10' deep in young alluvium; no fault reported, but no trench logs in report.
C-388	Woodward-Lundgren & Assoc.	San Ramon Valley High School	July 1971 Oct. 1971	680' trench, 15' deep in young alluvium; crosses air photo lineament. No fault observed. Human bones found at 8' depth, are partly mineralized; C^{14} analysis indicates minimum age of 2100 years bp (see C-416).

FER 109

TABLE 1 (cont.)

CDMG File #	Investigation Firm (or Geologist)	Site Description and Locality	Date of Report(s)	Comments
C-416	Woodward-Lundgren & Assoc.	Boone East School, San Ramon	Jan. 1972	730' trench in young alluvium, 16' deep; no fault reported. Trench crosses concealed trace of DWR. Human bones from 8' depth at nearby H.S. dated at 2100 years bp (minimum) (see C-388).
C-417	Earth Sciences Assoc.	Amador Valley High School Library, Pleasanton	Oct. 1975 Dec. 1975	12' deep trench, 450' long in young alluvium; magnetic and ER profile; no fault reported. Logs of trench published in Yadon & Wright (1979, Fig. 25 & 26).
C-463	Terrasearch			

State of California

Appedix A
To FER-109

The Resources Agency

Memorandum

CALIF. DIVISION OF
MINES & GEOLOGY

To : Earl Hart

79 SEP 12 A8:59

SAN FRANCISCO D.O.

Date: September 6, 1979

J. H. Bennett

From : Department of Conservation
Division of Mines and Geology
2815 O Street, Sacramento 95816

Subject: Pleasanton Fault

The following comments relate to the various surveys conducted on the Pleasanton fault at Camp Parks:

Horizontal Movement Data

(a) The NGS triangulation surveys (1964, 65, 69) indicate R/L movement of 18 mm (1964-69) at the PFS site, a possible 10 mm at the PFW site (1965-69), and no movement at the PFE site. The observed angle changes at PFS and PFW are significant and there is no apparent reason to question the validity of the data or the conclusions.

(b) We measured most of the lines in the PFS network during October, 1974 with our MA-100 Tellurometer. These lines were remeasured this past May (4.5 year interval). The comparative line lengths are summarized in Table 1. You will note that the two surveys are in excellent agreement indicating an absence of any lateral movement within the PFS network during this most recent period.

(c) The NGS surveys resulted from triangulation; those by CDMG are electronic distance measurements. While the data resulting from these two survey techniques are not strictly comparable, the good agreement between these surveys indicates that there was no continued lateral movement of any significance during the 1969-1974 period. The line lengths resulting from all the surveys at the PFS network are summarized in Table 2.

There is no apparent basis to discount the evidence for lateral fault movement having occurred during the period 1964-69. The absence of any lateral movement during the most recent 4.5 years (and very probably during the past 10 years) suggests that the earlier offset may have occurred during a period of aseismic creep. Creep need not be a continuous steady state process. Perhaps the occurrence of aseismic strain release in the form of steady state creep or one or more creep events during the 1964-69 period could have been related to the same strain release episode that was expressed seismically in the nearby Danville earthquake swarm of May-June 1970. Laser distance measurements suggested the possiblilty of 1 cm± of R/L movement on the Pleasanton fault during this swarm (Savage and Kinoshita, 1971).

Vertical Movement Data

(a) The two NCS leveling surveys performed during 1964 and 1965 clearly indicate subsidence west of the west branch of the Pleasanton fault. Gibson and Wollenburg (1968) attribute this to the fault acting as a low permeability ground water barrier. Geodetic leveling is extremely accurate over these short distances and the relative changes indicated by the surveys in the Camp Parks area are very credible. The time interval between the two surveys was very brief, only about 14 months.

(b) In January 1975, we completed a 1st-order releveling survey through all the marks that comprise the Camp Parks networks. Table 3 summarizes the results of the three surveys and the differences between the 1964-1975 surveys are contoured on Figure 1. All changes are computed relative to PFS-4 located in the SE corner of the network. It is immediately apparent that the relative changes that occurred during the decade 1965-75 are small, being of the same order of magnitude as those observed during the 14 month period 1964-65. The small changes that have occurred indicate additional relative subsidence of those marks located along the western margin of the networks, particularly PFS1 and PFS6. The subsidence pattern shown on Figure 1 is that which might be expected over a fault controlled ground water barrier.

I am curious, however, about the origin of the elongated topographic depression near the NW corner of the old parade grounds. This feature is directly on trend and if it should be a remnant of a former drainage course, perhaps the marks indicating the most subsidence may be responding because of their location within this old channel. The data presented by Gibson & Wollenberg (see their Figure 6) would, however, tend to negate this possibility.

Sometime during September, Gordon Chase and I will endeavor to run one or more detailed gravity and magnetic traverses in the immediate Camp Parks area or elsewhere if you have any suggestions.

Coincides with former drainage channel blocked by fill for rd. to SE by Army during 1940's. CWH

Jack

Jack Bennett

JB:it

Results of Fault Movement Surveys

Pleasanton Fault

August 1979

Network:

PFS, PFE-PFW (Established by National Geodetic Survey, 1964)

Location:

Spans the Pleasanton fault at Camp Parks, 5 km (3 miles) NNW of the City of Pleasanton, Alameda County, CA.

Survey Dates:

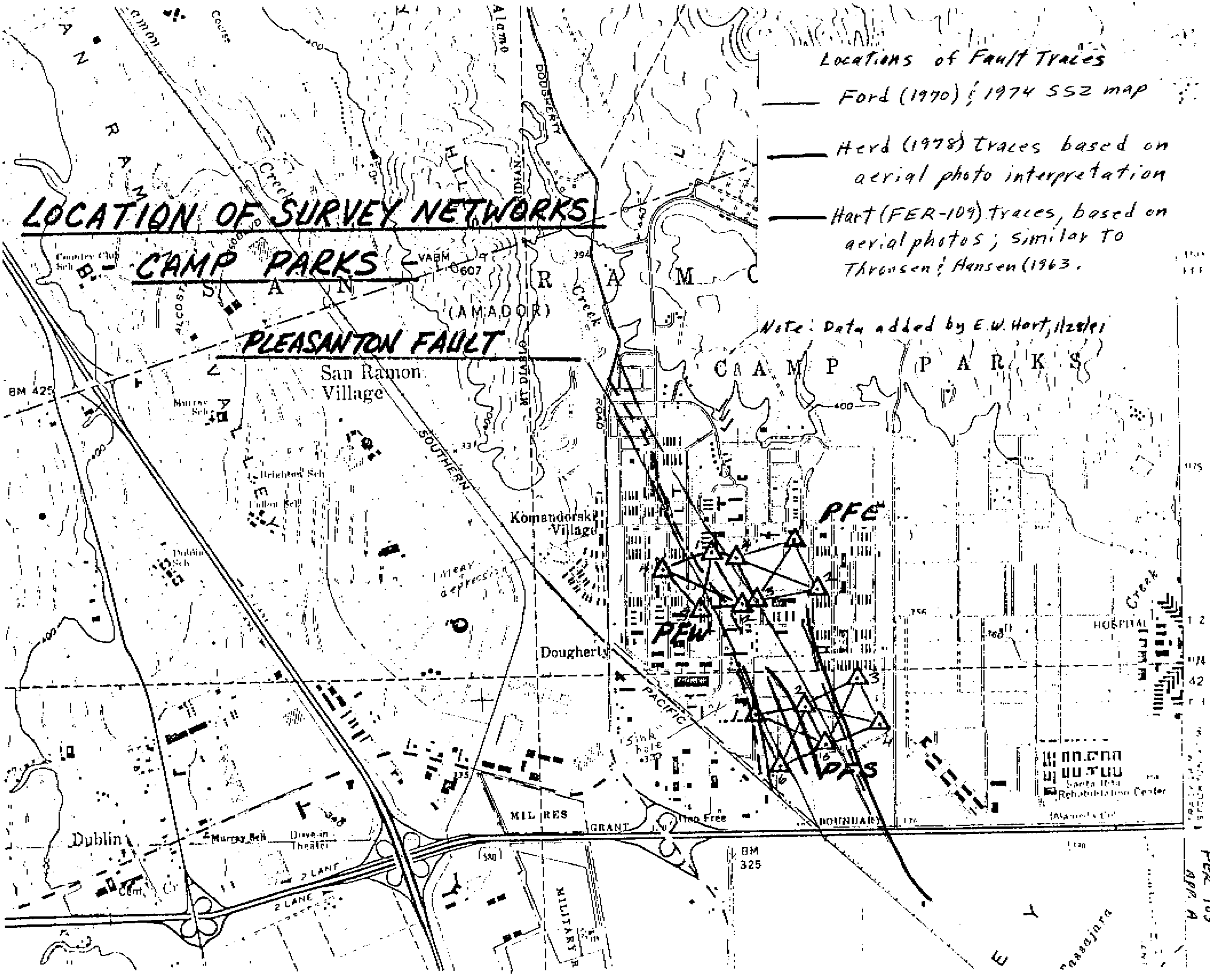
	NGS			CDMG	
Horizontal:	1964.3	1965.5	1969.8	1974.8	1979.4
Vertical:	1964.3	1965.5	--	1975.1	--

References to NGS Survey Results:

U.S. Dept. of Commerce, Coast and Geodetic Survey, June 1970, Study of earth movement determined by triangulation, Camp Parks, vicinity of Pleasanton, California.

Gibson, W.M. and H.A. Wollenberg, 1968, Investigations for ground stability in the vicinity of the Calaveras fault, Livermore and Amador Valleys, Alameda County, California, Geological Society of America Bulletin, v. 79, p. 627-638.

U.S. Dept. of Commerce, Coast and Geodetic Survey, August 1965, Report-Study of Earth Movement by Triangulation - Camp Parks, vicinity of Pleasanton, California.



LOCATION OF SURVEY NETWORKS
CAMP PARKS
PLEASANTON FAULT
Locations of Fault Traces
Ford (1970) & 1974 SSZ map
Herd (1978) traces based on aerial photo interpretation
Hart (FER-109) traces, based on aerial photos; similar to Thronsen & Hansen (1963.
Note: Data added by E.W. Hart, 11/28/81
PFC
PEW
PFS
linear depression
CAMP PARKS
SAN RAMON
San Ramon Village
Komandorski Village
Dougherty
Dublin
SOUTHERN PACIFIC
DOUGHERTY ROAD
MT DIABLO MERIDIAN
(AMADOR)
HOSPITAL
Santa Rita Rehabilitation Center
MIL RES
MILITARY
BOUNDARY
GRANT
Sink hole
Murray Sch
Drive-in Theater
BM 425
BM 325
VABM 607
2 LANE
FER-109 APP. A

PLEASANTON FAULT

TABLE 1

CAMP PARKS

PFS SITE

Comparative Line Lengths Resulting
from CDMG Distance Measurements 1974-1979

Sea Level Distance (meters)

LINE	OCT 1974	MAY 1979	DIFF (mm) 1979-74
5-6	n.m.	253.4794	--
5-4	324.4595	324.4591	-0.4
5-3	407.2359	407.2378	+1.9
5-2	242.0710	242.0714	+0.4
5-1	385.8957	385.8957	0.0
2-1	269.8522	269.8514	-0.8
2-3	297.5896	297.5934	+3.8
2-4	409.4210	409.4221	+1.1
2-6	338.3457	338.3436	-2.1
4-3	n.m.	289.9024	--
1-6	n.m.	n.m.	--

n.m. - not measured.

Line lengths determined by electronic distance measurement (Model MA-100 Tellurometer)

PLEASANTON FAULT

TABLE 2

CAMP PARKS

PFS SITE

Comparison of Line Lengths Resulting from NGS (triangulation) and CDMG (electronic distance measurement) surveys.

Sea Level Distances (meters)

LINE	NGS						CDMG		
	1964	Δ(mm)	1965	Δ(mm)	1969	Δ(mm)	1974	Δ(mm)	1979
2-5	242.067	+4	242.071	-2	242.069	+2	242.071	0	242.071
2-4	409.417	+9	409.426	+3	409.429	-8	409.421	+1	409.422
2-3	297.589	+6	297.595	+3	297.598	-8	297.590	+3	297.593
3-5	407.238	+6	407.244	-3	407.241	-5	407.236	+2	407.238
3-4	289.902	+9	289.911	-12	289.899		n.m.		289.902
4-5	324.457	+3	324.460	+6	324.466	-6	324.460	-1	324.459
2-6	338.350	+6	338.356	-6	338.350	-4	338.346	-1 2	338.345 4
1-2	269.840	+6	269.846	+9	269.855	-3	269.852	-1	269.851
1-5	385.881	+9	385.890	+9	385.899	-3	385.896	0	385.896
1-6	261.327	+6	261.333	-6	261.327		n.m.		n.m.
5-6	253.475	+6	253.481	0	253.481		n.m.		253.479

n.m. not measured.

PLEASANTON FAULT

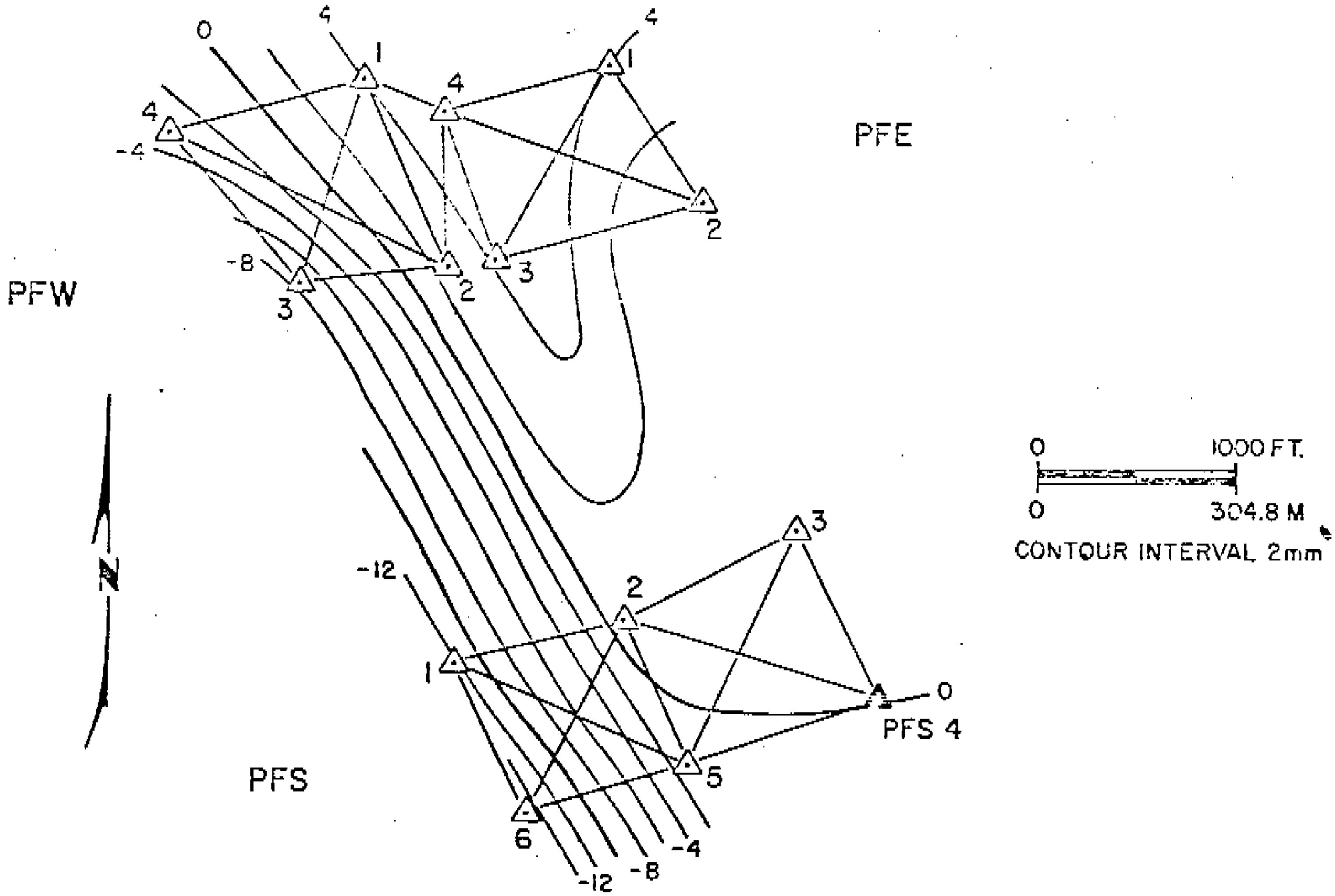
TABLE 3

CAMP PARKS

COMPARATIVE ELEVATIONS

BENCH MARK	NGS 1964 (APR-MAY)	1965-64 ΔH (mm)	NGS 1965 (JUN-JULY)	1975-65 ΔH (mm)	CDMG 1975 (JAN)	1975-64 ΔH (mm)
PFS 1	103.202	-7	103.195	-5	103.190	-12
PFS 2	104.825	+2	104.827	-1	104.826	+1
PFS 3	105.634	+2	105.636	-1	105.635	+1
* PFS 4	104.585	0	104.585	0	104.585	0
PFS 5	103.152	+1	103.153	-2	103.151	-1
PFS 6	101.924	-9	101.915	-6	101.909	-15
PFW 1	112.625	+2	112.627	+2	112.629	+4
PFW 2	107.464	+1	107.465	+2	107.467	+3
PFW 3	109.194	-7	109.187	-1	109.186	-8
PFW 4	110.301	-4	110.297	+1	110.298	-3
PFE 1	108.821	+1	108.822	+3	108.825	+4
PFE 2	107.430	0	107.430	0	107.430	0
PFE 3	107.184	+2	107.186	+2	107.188	+4
PFE 4	113.044	+3	113.047	+2	113.049	+5

* Elevation differences are computed relative to PFS 4 held as invariant in elevation. Regional surveys in 1964 and 1965 indicated no relative elevation change of this mark (Gibson and Wollenberg, Figure 6).



RELATIVE ELEVATION CHANGE DURING THE PERIOD 1964-1975 BETWEEN MONUMENTS COMPRISING THE PFS AND PFE-PFW SURVEY NETWORKS. CHANGES ARE RELATIVE TO PFS 4, HELD INVARIANT IN ELEVATION.

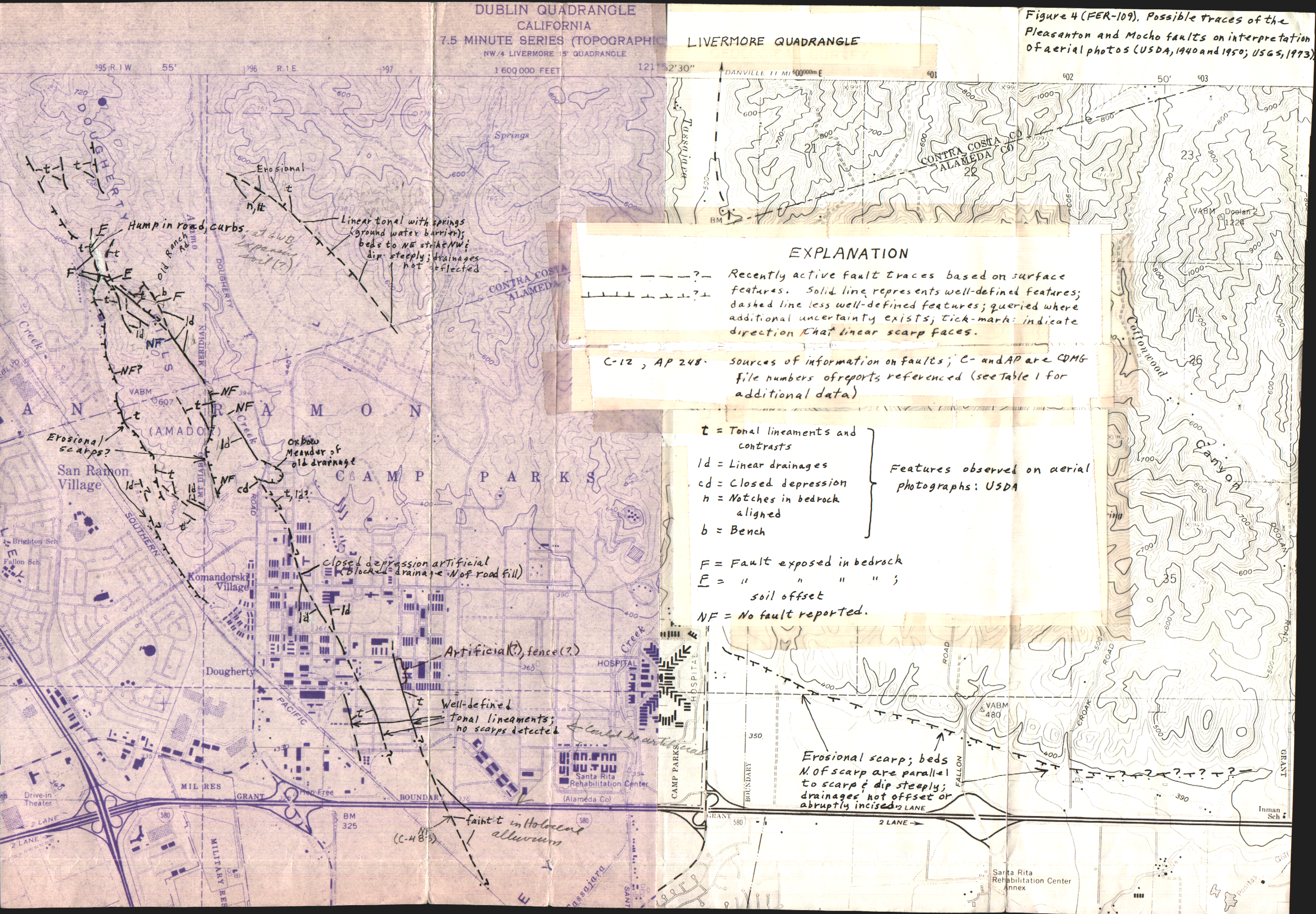


Figure 4 (FER-109). Possible traces of the Pleasanton and Mocho faults on interpretation of aerial photos (USDA, 1940 and 1950; USGS, 1973)